First Annual Report:

The Micro-pulse Lidar Worldwide Observational Network (MPL-Net)

Dr. Ellsworth J. Welton
Project Scientist, co-I
Goddard Earth Sciences and Technology Center, UMBC

Mr. James R. Campbell
Network Manager
Science Systems and Applications, Inc.

Mr. Timothy A. Berkoff
Instrument Manager
Goddard Earth Sciences and Technology Center, UMBC

Dr. James D. Spinhirne, PI
Dr. Si-Chee Tsay, co-I
Mr. Brent Holben, co-I
NASA Goddard Space Flight Center

1. Background

Measurements of cloud and aerosol physical and optical properties are needed for calibration/validation efforts by NASA EOS satellite projects, as data sets for a variety of modeling efforts, and for studies aimed at better understanding the role these atmospheric particles play in the global climate. There are many instruments capable of providing data products on cloud and aerosol properties. However, one key data product has been unavailable: long-term measurements of the vertical distribution of cloud and aerosol layers around the world. In particular, the vertical profile of cloud and aerosol layer heights and optical depths are required.

One instrument capable of providing this information is a lidar, which uses pulses of laser light to profile the vertical distribution of cloud and aerosol layers in the atmosphere. Despite this need, lidar systems prior to the 1990s were large, expensive, and not eye-safe which made them unsuitable for long-term worldwide deployments. During the 1990s the first small, autonomous, and eye-safe lidar system became available: the micro-pulse lidar, or MPL. The MPL has since been used successfully at a long-term site run by the ARM program and also in several independent field experiments around the world. Table 1 presents an overview of MPL related activities up to the present.

Current Funding and Support

In 1999, members of the Micro-pulse Lidar group at GSFC submitted a proposal to organize a worldwide network of MPL systems to provide long-term measurements of the vertical distribution of clouds and aerosols at sites around the world. The original proposal also included support for a limited number of field experiments each year. In the summer of 2000, NASA EOS agreed to fund the proposal, and the MPL-Net project was started. The CERES validation group at NASA LaRC contributed four MPL systems to MPL-Net, supplementing the existing stock of instruments. Finally, in the fall of 2000 the NASA SIMBIOS program agreed to fund another proposal to conduct lidar measurements from research vessels at sea (maximum of 2 cruises per year) using the SIMBIOS MPL system.

Satellite Validations

While MPL-Net is aiming to become the premier ground-based lidar observation network, the best platform for measuring the long-term distribution of cloud and aerosol layers worldwide is from a satellite based lidar. The Geo-Science Laser Altimeter System (GLAS) is the first such satellite lidar project, and is expected to launch in 2002. MPL-Net will serve as the primary ground validation tool for GLAS, and members of the MPL-Net staff are also on the GLAS atmospheric lidar team. MPL-Net is also useful to the ESSP3 satellite lidar project (formerly PICASSO-CENA), which is scheduled to launch a few years after GLAS.

What's in this report?

The following sections of this report each present a summary of five primary activities of the MPL-Net project: long-term sites, field experiments, data processing, MPL-Net web-site, and instrument improvements. A discussion of future work for each activity is also given. Appendix A and B present preliminary results from MPL-Net sites and field experiments, respectively.

2. Summary of MPL-Net Site Activities

The first two NASA funded MPL-Net sites have been established at the South Pole and at Goddard Space Flight Center. The South Pole site was established to support the EOS funded GLAS sensor on the ICESat platform. The NASA TOMS group has supplied their MPL system to the MPL-Net project since January 2001 for use as the MPL-Net home site at GSFC. In return, we have provided data processing for TOMS field experiments. In addition to our new sites, we have been working with the ARM program to help process the data from each of their MPL systems. The ARM program has MPL systems at the CART sites in Oklahoma, Alaska, and Manus and Nauru islands (the latter two in the tropical west pacific ocean). Including ARM, the current total of MPL-Net sites is six. Preliminary results from MPL-Net sites are presented in Appendix A.

Future Site Activities (FY02)

Planning is underway for the installation of the next MPL-Net site, in Jabiru Australia. The site is run by members of the Atmospheric Research division at CSIRO. The CSIRO group is currently constructing the site for the MPL and we plan to ship them an instrument by fall of 2001. The Jabiru site will also be part of both the AERONET and BSRN projects, and these other instruments will be co-located with the MPL.

The CERES validation group at LaRC has expressed interest in an MPL site at the Solar Village in Saudi Arabia. We will begin planning for this installation this fall, and should have an instrument available to send to the site in 2002.

Members of the Marine Meteorology Division at the Naval Research Labs (NRL) in Monterey, CA have agreed to provide funds to the MPL-Net project to construct a new MPL system (see section 6). Upon completion of the new MPL, we will ship it to them for installation as a new MPL-Net site. The new Monterey site should be operational by early spring 2002, in time for the next Asian dust season. The NRL group will also setup an AERONET site and the sunphotometer will be co-located with the MPL.

We have also been in contact with a group at the National Institute of Polar Research in Japan. They have an MPL in Norway, and have also just installed one on the coast of Antarctica. They have agreed to begin working with the MPL-Net project and will soon supply data from their site in Norway (and will submit data from the Antarctica site next year). In exchange for data, we will provide data processing and perform instrument repair/maintenance for them.

Finally, an agreement to support the ARM MPL sites will be finalized in the summer of 2001. The ARM program will provide funds for the maintenance and repair of their existing systems. After the agreement is final, we will begin to organize a structured upgrade of all of their existing systems. We will also begin to provide our most current data processing routines (see section 4) to the ARM program. The ARM MPL data products will be available through both the ARM web-site and the MPL-Net web-site (see section 5).

3. Summary of Field Experiment Activities

MPL-Net participated in five field experiments this past year: an ARM Cloud IOP, PRIDE, SAFARI, ACE-Asia, and TOMS[3]-F. A description of each experiment is given in Appendix B, along with some preliminary results. We note here in the summary that our involvement in the ACE-Asia experiment included funds to send a graduate student on a research cruise to acquire data and experience for his dissertation. This was the first such education/outreach effort for the MPL-Net project.

Analysis of data from two field experiments prior to the creation of MPL-Net also took place over the past year. Analysis of MPL measurements obtained during the 1999 Aerosols cruise and the Indian Ocean Experiment were completed during 2000. The height, spatial distribution, origin, and physical and optical properties of aerosol layers over the Atlantic and Indian Ocean were determined [*Voss et al.*, 2001; *Welton et al*., 2001; *Quinn et al.*, 2001a,b]. In addition, MPL results from INDOEX were used in a study demonstrating the possible impact of absorbing aerosols on cloud production over the ocean [*Ackerman et al*., 2000].

During our first year, MPL-Net participated in more field experiments than our original proposal indicated due to an urgent need for support of GLAS algorithm development. One of the primary objectives of MPL-Net was to support EOS satellite projects, and in particular, GLAS. The GLAS atmospheric science team (which includes members of MPL-Net) conducted an informal survey of the status of algorithm development in 1999. It was determined that a lookup table was required for a key parameter, the extinction-to-backscatter ratio (S-ratio). The S-ratio is required to accurately determine the optical depth and extinction for aerosol and cloud layers that do not have molecular signal returns below them. This includes all measurements of boundary layer aerosols. The survey found that there were not enough published measurements of the S-ratio to construct a useful lookup table. The ESSP3 project came to the same conclusion independently.

As a result of the survey, we chose to focus MPL-Net activities towards participating in a wide variety of field experiments that happened to occur during this past year. Each experiment took place in a region that allowed us to measure different types of aerosols along with a complete set of other crucial independent measurements (such as aerosol composition, temperature, humidity, etc). These measurements were aimed at determining S-ratio values for different aerosol types. At the same time, measurements of cloud properties were also conducted to aid the cloud S-ratio lookup table, even though the lookup table for clouds may not always be needed. The MPL-Net S-ratio data is being used to assemble the first version of the GLAS lookup table, and our data will also be used to construct the same type of table for the ESSP3 project.

Future Field Experiment Activities (FY02)

MPL-Net will participate in one last field experiment during FY01. An MPL will be deployed for the Chesapeake Lighthouse & Aircraft Measurements for Satellites (CLAMS) experiment during July of 2001. The MPL will acquire continuous measurements of aerosol and cloud layer heights at the Chesapeake Lighthouse site.

Results from all the completed field experiments in FY01 will be analyzed and the final data will be made available to the participants in each experiment. We will work together with other researchers in each experiment in the preparation of papers, reports, and conference presentations. At the moment, a lead author paper by EJW is planned and will focus on incorporating the S-ratio results from all the field experiments. This paper will present an overview of past and current S-ratio measurements, and discuss the new findings from the MPL-Net observations. This work will also be used to help produce the most accurate S-ratio global database in existence (to be used by both the GLAS and ESSP3 projects).

Two field campaigns and one research cruise are planned for FY02. The first field campaign will be MPL deployments to support GLAS during its post-launch 3 month calibration/validation phase (expected to be during spring/summer of 2002). GLAS will provide some funding for these cal/val deployments. One MPL will be deployed to the primary GLAS ground validation site at White Sands, New Mexico. In addition, one or two more MPL systems will be sent to locations surrounding the ARM site in Oklahoma. The surrounding sites will be situated so that GLAS will over-fly both the ARM site and the other MPLs during one track across the area. We will be able to compare the retrieval of results from the large horizontal resolution of GLAS to the small-scale resolution obtained from the series of MPL systems on the ground.

The second field campaign will be CRYSTAL-FACE during the summer of 2002 (if funded). A proposal has been submitted to participate in CRYSTAL-FACE, a cirrus cloud study in southern Florida. If the proposal is funded we will deploy a mobile MPL to the region and will observe cirrus clouds down/up wind of the primary ground sites (which contain other lidars).

One SIMBIOS funded research cruise will be performed during the spring of 2002. The cruise will cross from the North Atlantic to the South Atlantic Ocean and will allow for observations of both biomass and dust aerosols transported over the ocean from Africa.

Finally, the MPL-Net project is helping to support another graduate student's dissertation work this coming year. The graduate student is performing measurements related to ozone and biological productivity in the ocean. The student required observations of aerosol and cloud heights. The MPL-Net project is supporting the deployment of the TOMS MPL for this study, and will process the lidar data for the student (the experiment is local, here in Maryland).

4. Status of Data Processing Routines

Algorithms have been developed to process the large amount of lidar data acquired by MPL-Net sites and field experiments. The data processing routines are state-of-the-art algorithms built to work specifically with the MPL systems. Table 2 describes the MPL-Net data products.

Data processing proceeds in three steps. The first step is the NRB routine and involves correcting the raw signals for instrument effects [*Campbell et al.*, 2001]. The instrument effects are signal parameters not associated with returns from the atmosphere. The data resulting from the NRB routine are referred to as normalized relative backscatter (NRB). In the NRB data, all instrument parameters have been removed from the raw signals except a calibration constant. The next data processing step is the calibration routine. The calibration routine determines the calibration constant using aerosol optical depth measurements from a co-located sunphotometer (at MPL-Net sites we use AERONET). The data products from the calibration routine are referred to as attenuated backscatter signals and contain only atmospheric parameters. The final data processing step is the optical properties routine. The optical properties routine locates aerosol and cloud layer heights, and then calculates the optical depth of each layer. If the signal-to-noise is high enough, then the extinction-to-backscatter ratio (S) of the layer is determined, followed by both backscatter and extinction profiles through the layer.

Members of the MPL-Net staff have published descriptions of older routines [*Welton et al.*, 2000; *Welton et al.*, 2001] and also have numerous conference presentations on the subject. These older routines are similar to those we currently employ and formed the basis of the MPL-Net data processing code. One significant improvement of the earlier routines was expanding upon the initial error analysis code employed in the past. Complete error analysis for every step of MPL data processing has now been developed, and is currently being worked into our operational code. Also, the earlier code was designed to process small batches of data from field experiments. We are currently developing automated data processing routines to handle the large amount of data generated by MPL-Net activities. Automated NRB routines have been developed and are currently being tested. We estimate that the automated NRB routines we be fully implemented by July 2001.

Future Data Processing Activities (FY02)

Final NRB data files and images will be generated for all field experiments and for data collected at the South Pole and GSFC MPL-Net sites. In addition, these new NRB data products will be produced for all the ARM data, starting with the latest year's data from the Oklahoma site (and then working backwards). We will begin to incorporate automated processing of the NRB data from the Oklahoma and GSFC sites. Data from the other sites is not currently available in real-time. When new sites come online (see section 2), they will be incorporated into the automated processing.

Finally, we will begin to code the automated calibration and optical properties routines. Testing of these routines will be performed on our field experiment data as it is processed. The automated calibration and optical properties routines should be finished by the end of 2001.

5. Status of the MPL-Net Web-site

Development and implementation of data processing routines only form a portion of the overall data processing effort. The data products must be easily accessible by MPL-Net users (and the public in general), and must also be organized in a clear and manageable format. Therefore, a useful and responsive MPL-Net web-site (http://virl.gsfc.nasa.gov/mpl-net/) has been created to make data products, images, and MPL related information available to the public.

Data images from each site may be freely browsed by anyone, and an automated registration process has been developed to allow users access to actual data files. The process is automatic and no one is denied access to site data. We use this registration process so we can remain in contact with users and help them with analysis efforts, and also keep them informed of updates and improvements to the project as they occur. We have also been testing a simple web-based data file search process for registered users to download data files (the users will not need to separately login to an ftp server to get data, instead they access the data through the MPL-Net web-site). The NRB data files are being used to test this procedure.

Access to data from field experiments and cruises is also controlled through a similar registration process. However, only some experiments may have automated registration, for the others the MPL-Net staff will grant access after inspecting the request. The reason for this change in procedure is because MPL-Net often participates in field experiments organized by other groups. Most field experiments require that the data generated during the experiment is only available to actual participants, not the public, for a specified period after the end of the experiment. Therefore, we inspect each request during this time period and only grant access to those involved in the experiment. After the closed data period ends, the data is made public using the same automated registration process as discussed above. Also, in addition to simply making the normal MPL-Net data products available to the participants, we include a section on the web-site to post special requests by others in the experiment. We have found that this method is essential for successful interactions because experiments often require specific analysis that may not be accommodated in our normal automated data products.

The web-site also contains other useful resources for the MPL-Net staff and others associated with the project. These resources are contained in a section of the web-site open only to the staff and MPL-Net associates. We can view the list of MPL-Net web-site visitors, site registrations, and experiment registrations. Each list is updated automatically upon viewing and is therefore always current. There is also a section containing a list and agenda of upcoming MPL-Net meetings and also summaries of past meetings. Finally, we are also able to obtain near-real-time MPL computer screen images from each site (except ARM, though that may change soon). The screen images show the lidar raw signal image, as well as various instrument parameters such as detector temperatures, background sunlight, date/time (etc). The screen images are used as a diagnostic tool for assessing each instrument, they also provide an interesting near-real-time view of the conditions at each site.

The MPL-Net visitor file (viewable from the staff web-site) contains the visitor's server name, IP number, date/time of visit, and number of visitors in total. The visitor list is used to assess how well MPL-Net is serving the needs of the research community and public in general. Figure 1 displays the visitor statistics through June 2001. Analysis of the visitor information allows us to determine if we need to improve communication with groups that may not be aware of our project or find our data unusable for some reason. In either case, such information helps assess our performance and improve the project.

Future Web-site Activities (FY02)

We have begun testing an on-line searchable database for downloading data files from sites and field experiments. We plan to have the database fully functional by the end of summer 2001. The database will allow MPL-Net users to search for data files from a specific site or experiment, and for a specific period of time. The database will initially only contain the NRB data files, in netCDF format. When we have implemented the automated optical properties routine (see section 4) we will make the remaining data products available as well.

6. Status of MPL Instrument Improvements

Progress has begun on improvements to the original MPL design. The improvements incorporate advances in technology since the origin of the MPL in the early 1990s, as well as experience with the original design over several years. The improvements were deemed necessary in order to reduce instrument down-time and also increase the quality of the data products. The new design will enable servicing of MPL systems in the field, and also increase their long-term stability. Existing MPL systems, including those in the ARM program (see section 2), will be gradually upgraded to include all components in the new design. The upgrades will be completed in such a way as to not interfere with normal MPL-Net operations. However, brand new MPL systems, such as the one funded by NRL (see section 2), will be completely assembled in the new configuration prior to installation as a new MPL-Net site.

There are five main areas of improvement in the new design: telescope, detector, laser, data system, and the mechanical parts/housing. Work on the first two has already begun.

We have field-tested a new rugged telescope in two MPL systems over the past year. The new telescope lessens the concern of optical misalignments during shipping and installation in the field, and also allows for faster repair work in the lab.

We also completed work on a prototype MPL system with a new style of detector. The new detector style is fiber coupled to the optical path. The older detector arrangement was fixed in place as part of the optical path and created many problems. The most important related to detector failure. If the detector failed, then a complete re-alignment procedure (by a trained engineer) on a collimator was required. Therefore, MPL success or failure during a field deployment was completely dependent upon the detector. Use of the fiber-coupled detector will eliminate this concern because a blown detector can be simply removed and a new one screwed onto the end of the fiber by someone with minimal training. Also, the latest detectors from the manufacturer have new surge protection circuitry and should greatly reduce the number of detector failures.

Future Instrument Activities (FY02)

We have placed an order for a laser system from a new company. The new laser system has the same basic specifications as the original, however it contains a more powerful diode. As a result, running the new diode at the old power setting (about 1/10th of the new maximum) will enable a much longer laser lifetime. We could also boost the laser output energy because we are far from the eye-safety limit. We estimate that a small boost in laser power would increase our signal-to-noise, and still give a longer overall lifetime while remaining eye-safe. Finally, we expect to have much better customer service from the new company thereby decreasing down-time during instrument repairs.

We will develop a new data acquisition system (DAS) for the MPL. The new DAS will allow for more efficient post-processing of the raw data using our automated routines (see section 4). In addition, we will be able to control the entire MPL system (including the laser) using the DAS. This will greatly enhance our remote site operations. The new DAS will be provided by a local Goddard contractor that has already developed a similar DAS for the ER-2 Cloud Physics Lidar (CPL). The cost of developing the DAS has already been provided by the CPL project, and with only a few minor alterations the DAS can be used for the MPL. The majority of work will involve redesigning the real-time DAS software, however we expect this to be minimal. The first new DAS should be available for testing by the end of 2001.

Finally, we are planning to redesign the mechanical parts, mounts, and housing for the new MPL design. The new telescope and detector require us to use a new housing as the old one was not designed to fit these parts. In doing so, we will obtain a more rugged overall housing then the original. The mechanical work will be performed using a local Goddard contractor.

We estimate that the first complete prototype of the new MPL design (referred to as type 4) will be finished by the end of 2001. Gradual upgrades of existing MPL systems will proceed during next year, with primary emphasis placed on upgrading detectors to the new fiber-coupled arrangement.

Appendix A: Preliminary Results from MPL-Net Sites

South Pole

Figure 2 displays some of the first data taken at the South Pole site on January 10, 2000. Figure 2a shows the attenuated backscatter lidar signal, Figure 2b shows the backscatter profile obtained from the MPL signals, and Figure 2c shows the column optical depth throughout the day. The unique structure of the atmosphere over the South Pole has been identified during our first year of observations. Initial findings show that there are no boundary layer aerosols, instead blowing snow and low laying clouds are typically present. The height and concentration of blowing snow at the Pole is important to the GLAS mission because the snow can cause multiple scattering in the GLAS lidar beam near the surface, which can interfere with the GLAS polar altimetry mission. Clouds can have the same effect, but the GLAS lidar will detect them. GLAS will not be able to detect low level blowing snow. So far we have found that when the wind subsides the blown snow disappears and if there are no clouds present then we typically obtain only molecular lidar profiles from near the surface to the stratosphere.

We have also observed some cases of suspected polar stratospheric clouds (PSC) during the southern hemisphere winter months. Figure 3 shows data taken from June 11 to June 17, 2000. The presence of high altitude (~ 20 km) signal returns are shown in the MPL signals. We believe that these signal returns are PSC, and will soon begin analyzing this period.

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Figure 4 displays MPL data from the GSFC site on April 13, 2001. Figure 4a shows the uncalibrated MPL signal, and Figure 4b and 4c show the GSFC AERONET aerosol optical depth and angstrom exponent respectively. The data shows the first appearance of Asian dust (as seen by MPL-Net) over the east coast, as a result of a large dust storm over China about one week earlier. The appearance, at about 1930 UTC, of the intense scattering layer at 5 to 6 km coincides exactly with a significant drop in the angstrom exponent (indicating the sudden appearance of large particles). The TOMS group at GSFC also indicated that they had tracked the dust plumes from China and that dust should have been overhead at that time. The MPL data collected over the following month showed that possible dust layers continued to appear over GSFC. The data from this time period will be merged with MPL data collected during the ACE-Asia experiment (same time frame, see Appendix B) to see if MPL-Net instruments tracked the dust plume during different parts of its journey.

The data from the GSFC MPL-Net site is also being used in an inter-comparison effort with other Goddard lidars, including the Scanning Raman Lidar (SRL), the Aerosol/Temperature Lidar (ATL), and the ALEX Raman lidar at UMBC. This work is fostering interesting and valuable collaborations within the GSFC lidar community. In particular, use of the Raman lidars will allow for a more accurate assessment of the MPL data processing routines and procedures. In turn, MPL studies at our remote sites may lead to a better understanding of how to use complicated and expensive lidar systems like the Raman.

Appendix B: Preliminary Results from Field Experiments and Cruises

ARM Cloud IOP 2000

The first was an ARM cloud IOP centered at the CART site in Oklahoma (also an MPL site). Two additional MPL-Net systems were sent to positions around the central site in order to study differences in the cloud properties over a large region. Figure 5 shows an example of data acquired on March 6, 2000. The 1 minute raw data was analyzed (no higher time average was applied) to test the feasibility of studying clouds at high temporal resolutions. Figure 5a shows the attenuated backscatter lidar signals, Figure 5b shows the recovered aerosol and cloud backscatter profiles, and Figure 5c shows the column optical depth. In general, we find that both aerosol and cloud layer heights can be determined accurately at 1 minute time resolutions. However, longer time averages are often required for accurate determination of optical properties such as backscatter and optical depth, especially for cirrus clouds.

PRIDE

The second experiment was a Navy/NASA sponsored Saharan dust study in Puerto Rico (PRIDE). One MPL was sent to the PRIDE ground site to provide continuous measurements of Saharan dust properties overhead. Figure 6 shows an example of data acquired from July 5 to July 10, 2000. Figure 6a shows the attenuated backscatter lidar signals at 1 minute time resolution. Two dust episodes, the first from day 187 to 189, and the second from 191 to 193, occurred during this time period. A dust free period occurred between the two (from 189 to 191).

The signals were cloud screened below 5 km, and then averaged for 5 minutes before processing layer heights and optical properties because the focus of PRIDE was to study Saharan dust in the lower troposphere (locating cirrus clouds was also important for work with the MODIS validation team). Figure 6b shows the resulting aerosol and cirrus layer backscatter profiles, and Figure 6c shows the aerosol plus cirrus optical depths.

Our focus for participating in PRIDE was to measure S-ratios in a marine environment impacted by Saharan dust. Dust transported over the oceans will cause problems for GLAS retrievals because the presence and location of the dust layers is variable. In many cases, GLAS must assume the S-ratio, using a default lookup table, before processing the data. The current GLAS database, and other published literature [*Ackermann*, 1998; *Welton et al.*, 2000], assumes that the marine S-ratio would be 25 to 30 sr during PRIDE, and that the dust S-ratio would be ~ 40 sr. The measured MPL average S-ratio during the two dust periods was ~ 43 sr, and the average S-ratio during the dust free period was ~ 24 sr.

SAFARI 2000

The third experiment was sponsored by NASA EOS and focused on studies of bio-mass aerosols in Southern Africa during the SAFARI-2000 campaign (August – September 2000). One MPL was deployed in Mongu, Zambia and another in Skukuza, South Africa during SAFARI-2000. The data from both MPL systems are currently being analyzed and final data products are expected by summer of 2001.

ACE-Asia

The fourth experiment, ACE-Asia, was sponsored by NSF and NOAA. The aim of ACE-Asia was to study pollution and Asian dust plumes over Japan, Korea, the Yellow Sea, and surrounding regions during March and April 2001. One MPL was deployed to Dunhuang, China to study Asian dust at it's source region. Another MPL was deployed onboard the NOAA ship R/V Ronald. H. Brown, to acquire dust and pollution profiles over the ocean and also to provide data to the NASA SIMBIOS ocean color validation program (ship cruise funded by SIMBIOS). The experiment just ended and the data will be processed starting this summer, and into fall 2001.

A graduate student from the University of Miami was sent on the ship cruise to operate the MPL. Data from the cruise will be used in the student's dissertation. This was the first education outreach effort of the MPL-Net project, and it demonstrates the unique opportunity that MPL-Net can offer to graduate students that would not otherwise have been able to take advantage of participating in such a large international experiment.

TOMS^3-F

The fifth experiment was sponsored by NASA's TOMS project. The experiment, TOMS^3-F, took place in Alaska and was conducted to identify the source(s) of total ozone offsets from various measurement platforms at high Northern latitudes. MPL-Net helped support the deployment of the TOMS MPL system to Fairbanks, Alaska in March 2001. The experiment recently ended and the data will be processed starting this summer and into fall 2001.

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Campbell, J. R., E. J. Welton, J. D. Spinhirne, and C. J. Flynn, Global Lidar Observations For Cloud and Aerosol, ARM Science Team Meeting, March 2001.

Collins, W. D., P. J. Rasch, E. J. Welton, T. Beck, and J. D. Spinhirne, Assimilation of Space-based Aerosol Lidar Measurements for Studying African Dust: Methodology, AGU Fall Meeting, Dec 2000.

Spinhirne, J. D., J. R. Campbell, D. L. Hlavka, V. Stanley Scott, and Conner J. Flynn, Autonomous, Full-time Cloud Profiling at ARM Sites with Micro-pulse Lidar, AMS Meeting, Jan 2000.

Welton, E. J., J. R. Campbell, J. D. Spinhirne, and V. S. Scott, Global monitoring of clouds and aerosols using a network of micro-pulse lidar systems, SPIE Symp. Rem. Sens. Atmos. Environ. Space, Sendai, Japan, Oct 2000.

Welton, E. J., J. R. Campbell, and J. D. Spinhirne, Measurements of Dust Vertical Profiles and Optical Properties Using Micro-pulse Lidar Systems, AGU Fall Meeting, Dec 2000.

Table 1

Name	Location	Dates	Type
ARM – SGP	Oklahoma, USA	1993 - Present	Site
ARM - Manus	Manus Island	1996 - Present	Site
ARM - North Slope	Alaska, USA	1998 - Present	Site
ARM - Nauru	Nauru Island	1998 - Present	Site
ACE - 2	Canary Islands	Jun - Jul 1997	Exp
MOCE - 4	Trop. N. Pacific Ocean	Jan 1998	Cruise
INDOEX	Maldives	Feb - Mar 1999	Exp
INDOEX	N. & S. Indian Ocean	Feb - Mar 1999	Cruise
MPL-Net - SPARCLE	South Pole	Dec 1999 - Present	Site
ARM Cloud IOP	Oklahoma, USA	Mar 2000	Exp
PRIDE	Puerto Rico	Jun - Jul 2000	Exp
SAFARI	S. Africa, Zambia	Aug - Sept 2000	Exp
MPL-Net - GSFC	Maryland, USA	Nov 2000 - Present	Site
ACE-Asia	Pacific Ocean, China Sea	Mar - Apr 2001	Cruise
ACE-Asia	China	Mar - Apr 2001	Exp
TOMS^3-F	Alaska	Mar – Apr 2001	Exp.

MPL Developed at NASA/GSFC For Work in ARM Program

- First MPL at ARM CART Site

MPL Used For Independently Funded Experiments/Cruises

- ACE-2 First Experiment Using MPL (Dust Meas.)

Micro-pulse Lidar Network (MPL-Net) Started

- Organize MPL Activities at GSFC, and Provide Long-term Meas. of Aerosol/Cloud Vertical Structure at Key Sites Around the World
- First MPL-Net Site at the South Pole
- MPL-Net Supports Field Experiments/Cruises

http://virl.gsfc.nasa.gov/mpl-net/

List of Abbreviations:

ARM: Atmospheric Radiation Program
GSFC: Goddard Space Flight Center
ACE-2: Aerosol Characterization Experiment 2
MOCE-4: Marine Optical Characterization Experiment 4
SAFARI: Southern African Regional Science Initiative
MPL-Net: Micro-pulse Lidar Network
IOP: Intensive Field Phase
INDOEX: Indian Ocean Experiment
PRIDE: Puerto Rico Dust Experiment
ACE-Asia: Aerosol Characterization Experime
TOMS^3-F: Total Ozone Measurements by Satellites, Sondes, and Spectrometers at Fairbanks

Table 2

Data Product #	Data Product Description
MPL 00	Raw MPL Signals (daily archived binary data)
MPL 01	Normalized Relative Backscatter Signal (Corrected MPL Signal)
MPL 02	Attenuated Backscatter Signal (Corrected and Calibrated MPL Signal)
MPL 03	Aerosol and Cloud Layer Boundary Heights
MPL 04	Optical Depth of Each Aerosol and Cloud Layer (Optical Depth of Whole Layer)
MPL 05	Backscatter, Extinction, and Optical Depth Profiles of Each Layer Extinction-Backscatter Ratio (S-ratio) of Each Layer

Figure 1

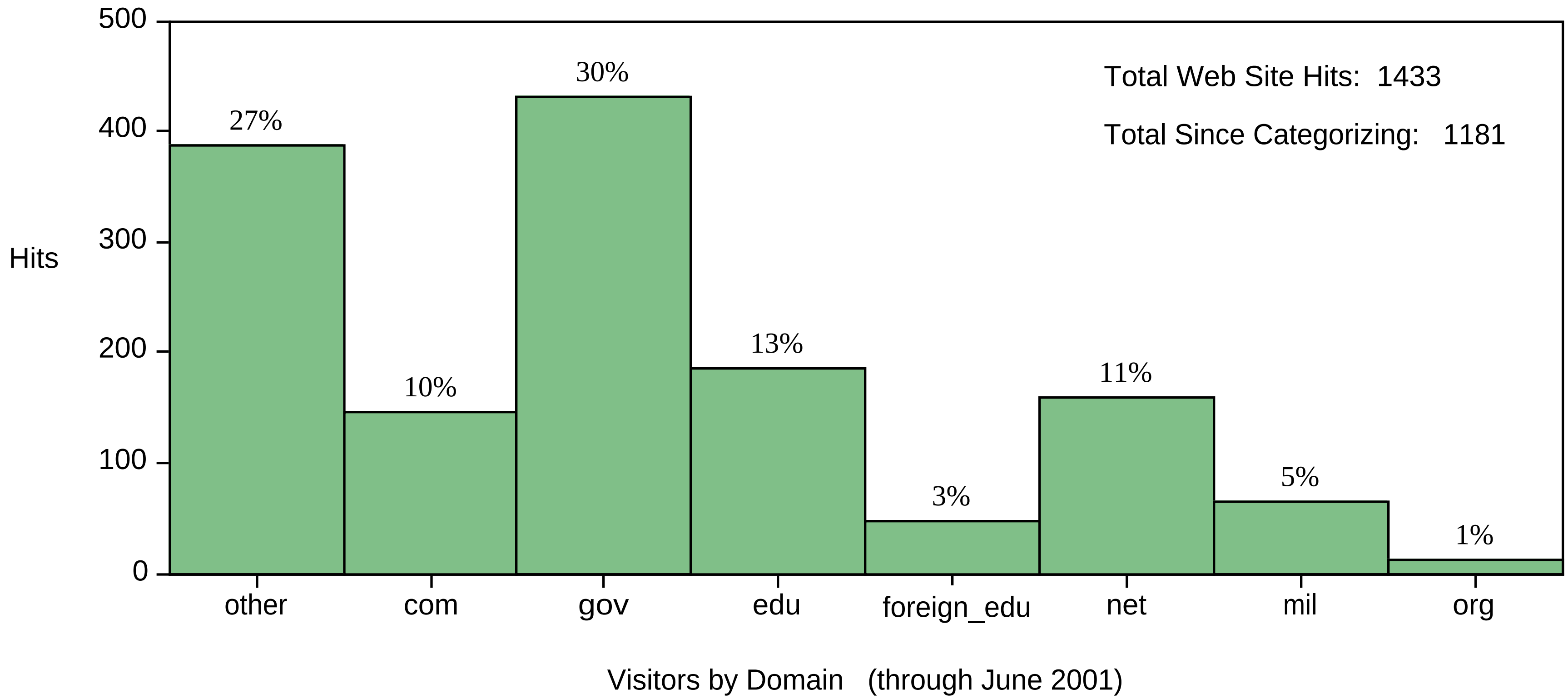

500
400
300
200
100
0
Hits
27%
10%
30%
13%
3%
11%
5%
1%
Total Web Site Hits: 1433
Total Since Categorizing: 1181
other
com
gov
edu
foreign_edu
net
mil
org
Visitors by Domain (through June 2001)

Figure 2

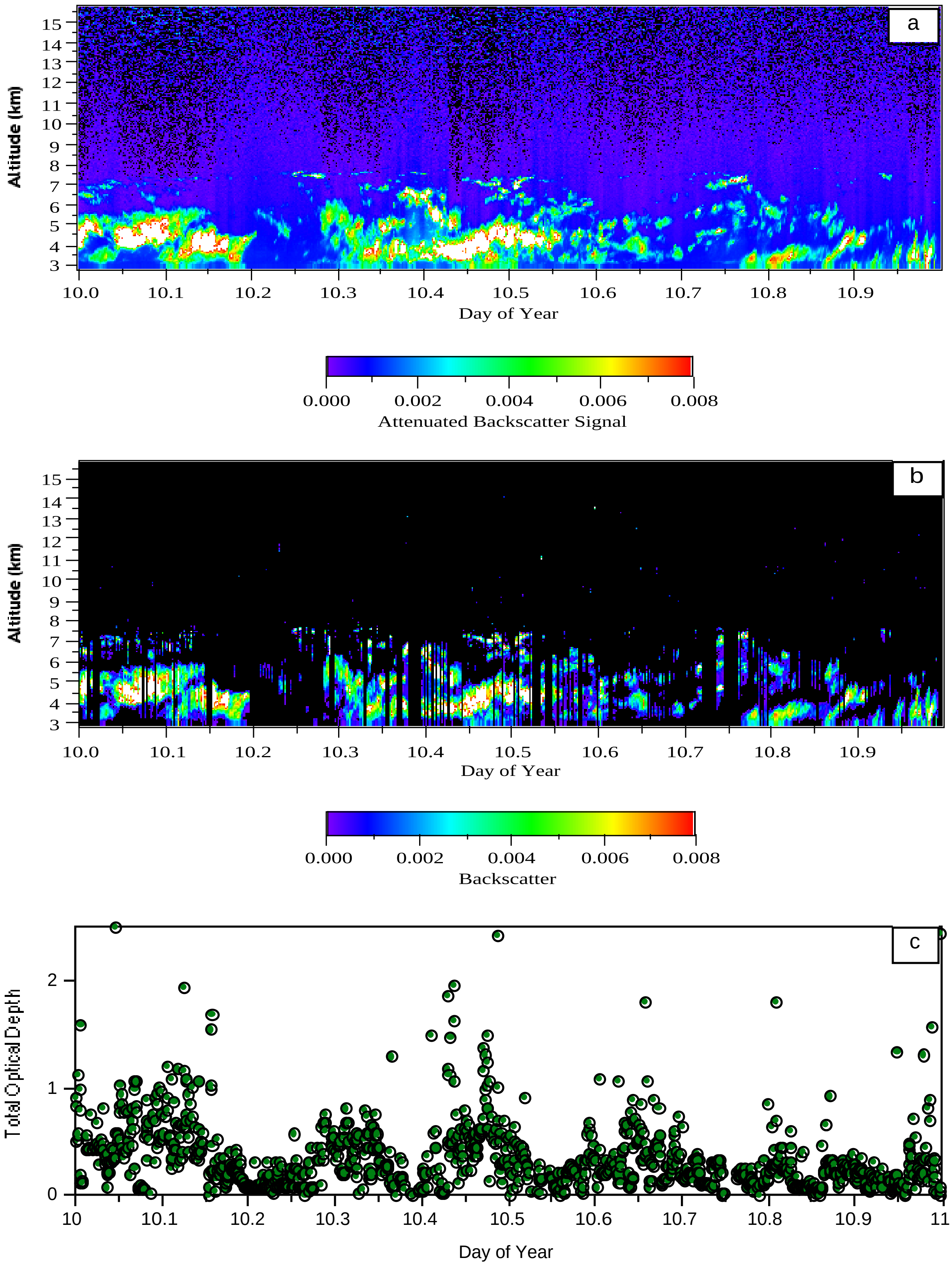
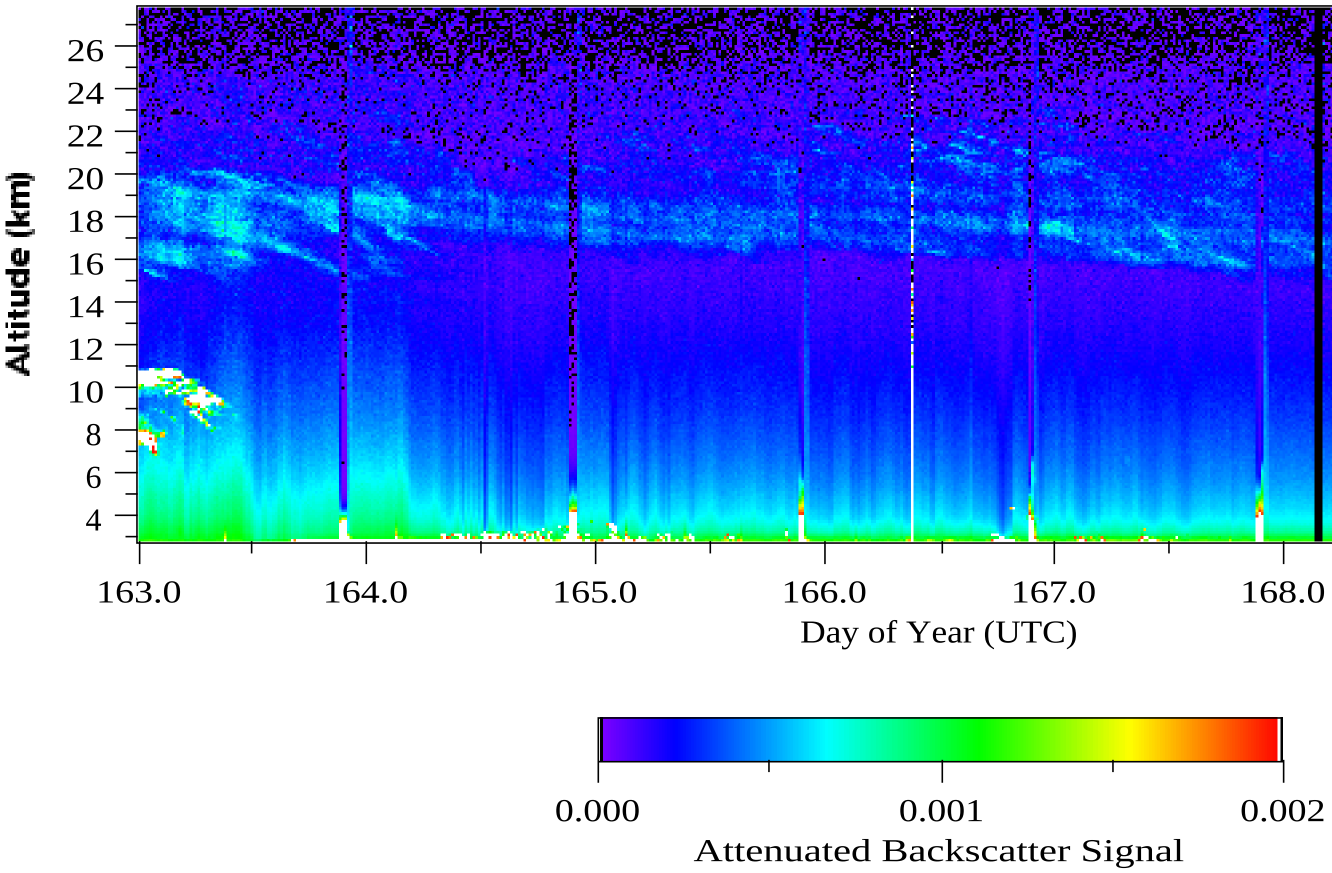

a
Altitude (km)
15
14
13
12
11
10
9
8
7
6
5
4
3
10.0
10.1
10.2
10.3
10.4
10.5
10.6
10.7
10.8
10.9
Day of Year
0.000
0.002
0.004
0.006
0.008
Attenuated Backscatter Signal
b
Altitude (km)
Day of Year
0.000
0.002
0.004
0.006
0.008
Backscatter
c
Total Optical Depth
2
1
0
10
10.1
10.2
10.3
10.4
10.5
10.6
10.7
10.8
10.9
11
Day of Year

Figure 3



Altitude (km)
26
24
22
20
18
16
14
12
10
8
6
4
163.0
164.0
165.0
166.0
167.0
168.0
169.0
Day of Year (UTC)
0.000
0.001
0.002
Attenuated Backscatter Signal

Figure 4

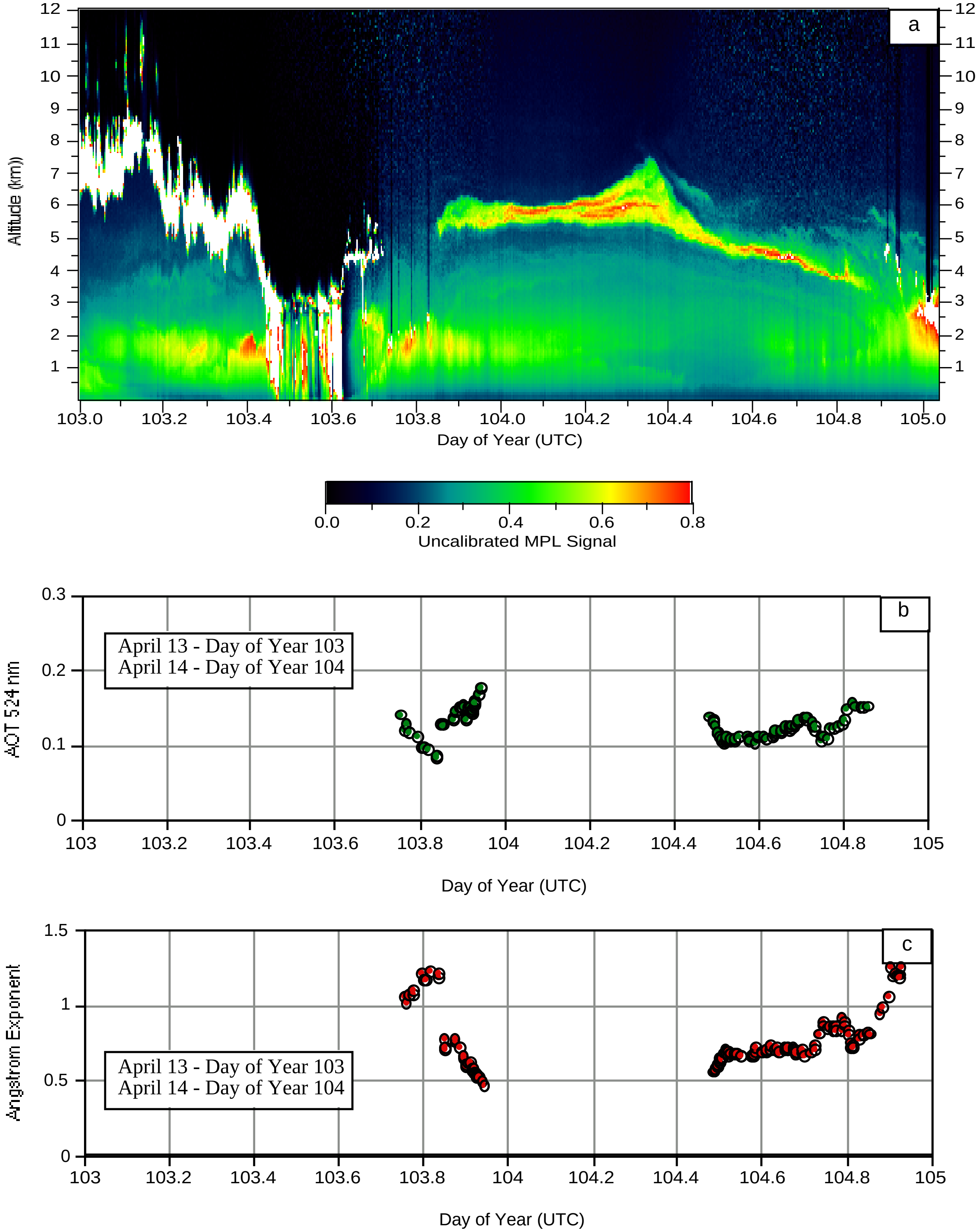

a
Altitude (km)
Day of Year (UTC)
Uncalibrated MPL Signal
b
April 13 - Day of Year 103
April 14 - Day of Year 104
AOT 524 nm
Day of Year (UTC)
c
April 13 - Day of Year 103
April 14 - Day of Year 104
Angstrom Exponent
Day of Year (UTC)

Figure 5

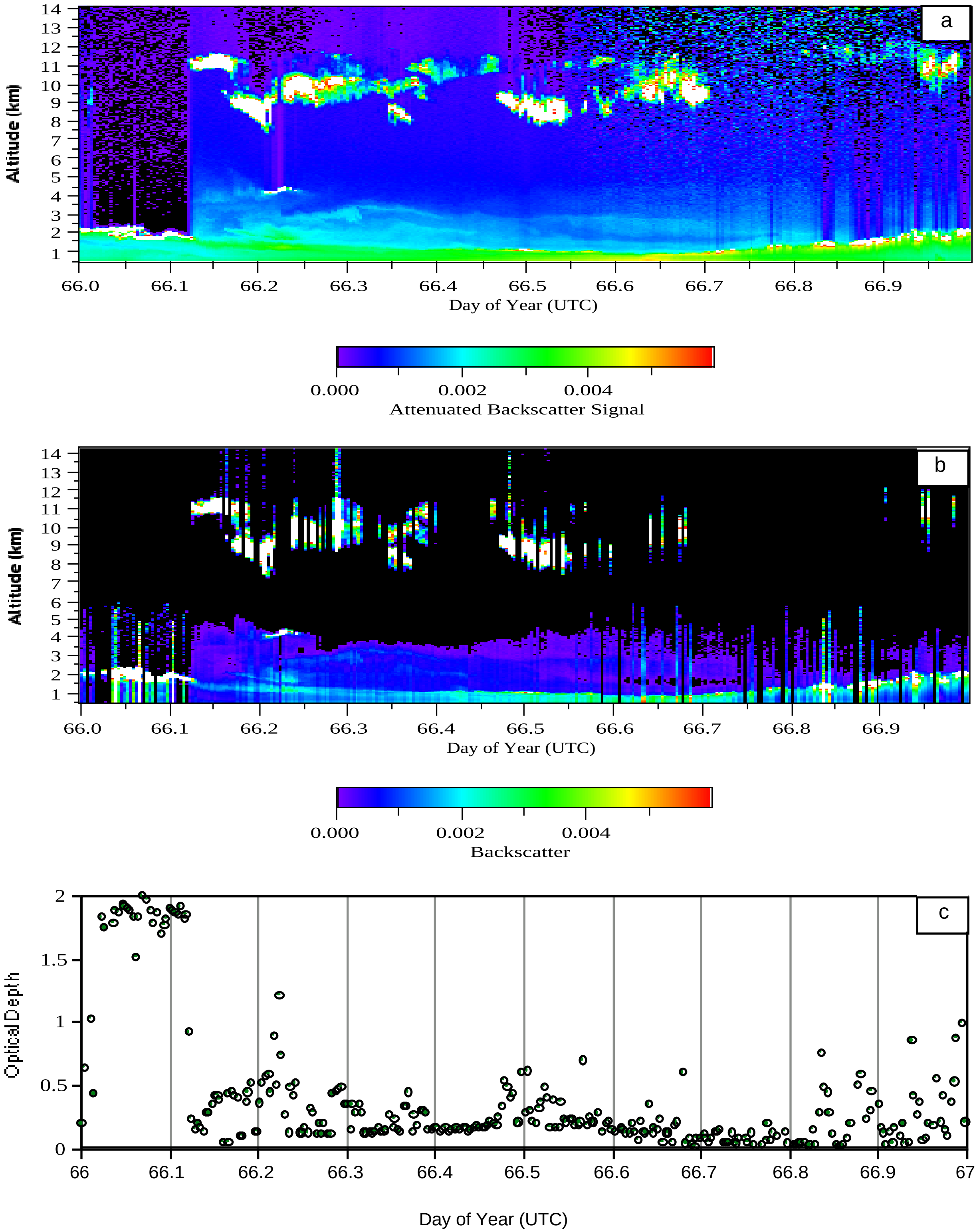
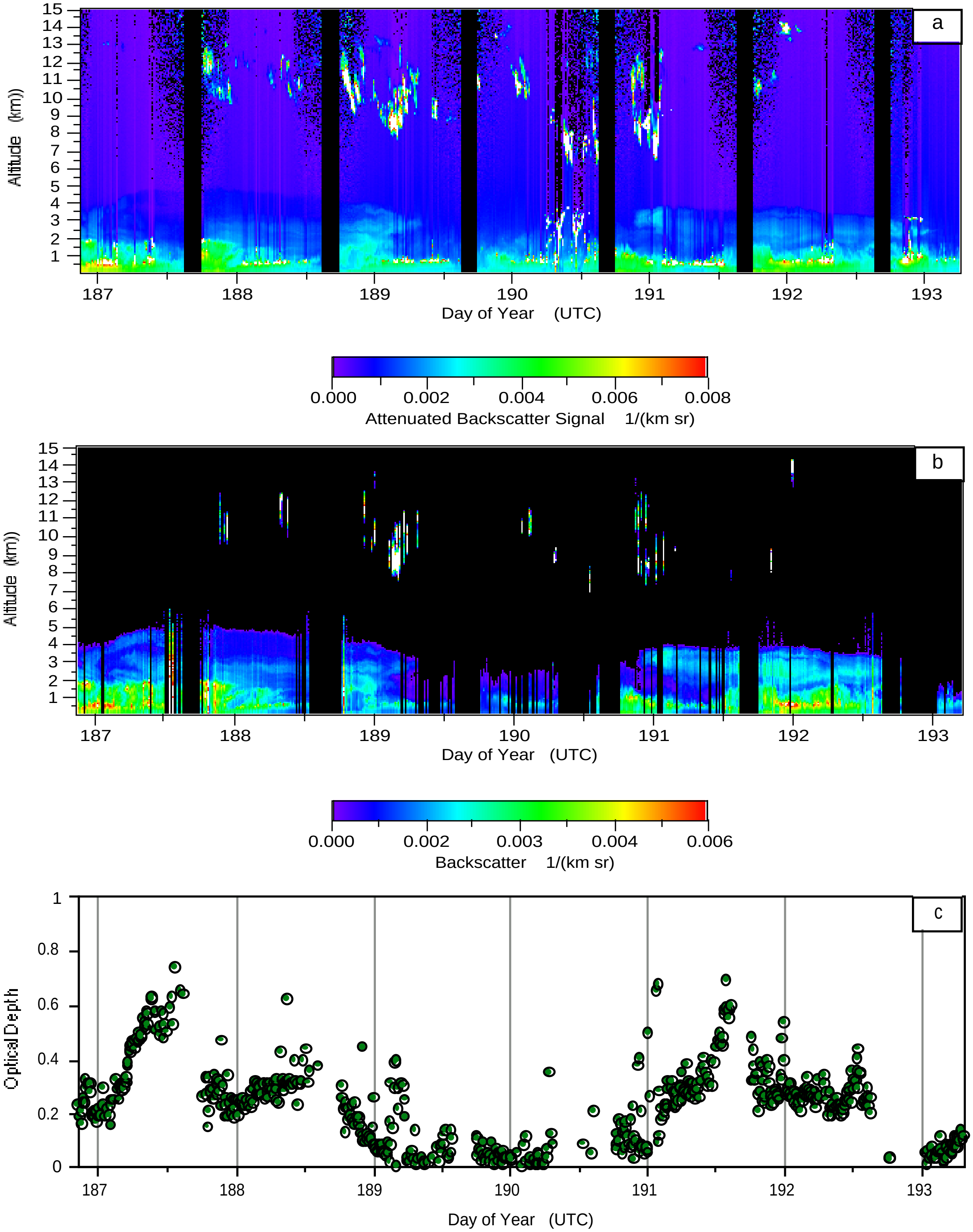

a
Altitude (km)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
66.0
66.1
66.2
66.3
66.4
66.5
66.6
66.7
66.8
66.9
Day of Year (UTC)
0.000
0.002
0.004
Attenuated Backscatter Signal
b
Altitude (km)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
66.0
66.1
66.2
66.3
66.4
66.5
66.6
66.7
66.8
66.9
Day of Year (UTC)
0.000
0.002
0.004
Backscatter
c
Optical Depth
2
1.5
1
0.5
0
66
66.1
66.2
66.3
66.4
66.5
66.6
66.7
66.8
66.9
67
Day of Year (UTC)

Figure 6


a
Altitude (km)
Day of Year (UTC)
0.000
0.002
0.004
0.006
0.008
Attenuated Backscatter Signal 1/(km sr)
b
Altitude (km)
Day of Year (UTC)
0.000
0.002
0.003
0.004
0.006
Backscatter 1/(km sr)
c
Optical Depth
Day of Year (UTC)